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The micro-Crustacea and physico-chemical features of temporary ponds near Northcliffe, Western Australia

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Abstract

Thirty five micro-crustacean species were recorded in seven temporary ponds located between Northcliffe and Windy Harbour, Western Australia, sampled in 1977, 1980 and 1990. Three physico-chemical parameters were determined for seven ponds in 1977 and six parameters for four ponds in 1980. Ponds varied in acidity, but high acidity did not lower species richness; one pond with a pH of 4.2-4.5 had the highest mean species richness. Species endemic either to the Northcliffe region or to south-western Australia are *Daphnia occidentalis, Calamoecia elongata, C. attenuata, Boeckella geniculata, Hemiboeckella andersonae, Paracyclops* sp. nov. and *Biapertura imitatoria*. The following species are regarded *pro tem* as being acidophilic: *D. occidentalis, C. elongata, P.* sp.nov., *B. imitatoria, B. longinqua, Monope reticulata* and *Rak obtusus. Hemiboeckella searli* and *Metacyclops* sp. (cf. *arnaudi*) appear early in succession. *H. andersonae* may also appear early, or may be delayed. Unlike the fauna of lotic environments in the study region, there are presently no sound data for concluding that the micro-crustacean fauna of lentic environments is impoverished relative to that in south-eastern Australia.

Introduction

The moist south-west corner of Western Australia is of outstanding interest from the viewpoint of both phytogeography (Hopper 1979, Nelson 1981) and zoogeography (Kikkawa *et al*. 1979). With respect to the freshwater fauna, there is a high degree of endemism in Western Australia (Maly & Bayly 1991, Frey 1991), and a high proportion of these endemics occur in, or are restricted to, the far south-west of that State.

Although various freshwater taxa occurring in this region have received attention by taxonomic specialists, more comprehensive studies of fresh waters in the Northcliffe-Walpole region commenced only recently. Bayly (1982) published a brief account of the ecology of temporary pools on granite outcrops in southern Western Australia, including six small pools located within a 15 km radius of Northcliffe, each of which was sampled three times during the winter of 1977. Pusey & Edward (1990) studied the invertebrate ecology of nine sites including two temporary pools which are in the same region as the seven ponds discussed in the present study.

The present study overlaps in a temporal sense with that of Bayly (1982) but excludes water bodies lying directly on granite rock substrata. The study had two main aims: to establish for zoogeographic purposes the precise nature of the micro-crustacean fauna of the temporary waters, and to examine some general aspects of the ecology of the waters that are highly distinctive in a chemical sense.

Study Area

The study area (Fig 1) is located in the mesic far south-west corner of Western Australia where the summers are dry and the winters are wet.

Rainfall data for Pemberton for the 1977 sampling period are presented in Fig 2A; the three sampling dates occurred 19, 33 and 47 days after the break of the wet season (16 May). Rainfall data relevant to the 1980 sampling are given in Fig 2B; the break occurred on 17 April and the first sampling did not occur until 49 days later.

The location of the ponds is shown in Fig 1. Ponds 1 and 2 were located 2.3 km (by road) south of Northcliffe on formerly forested land which had been cleared and put into pasture. These two ponds were scarcely separated from each other and with high rainfall would become confluent. Both of these ponds had well developed macrophyte beds in which *Callitriche* L. was dominant and *Cotula coronopifolia* L. also occurred. Pond 3 (6.0 km south of Northcliffe) lay on, and was surrounded by, natural swamp land with large clumps of *Juncus* L. but the water had probably been impounded by road construction. It contained dark, humic water and extensive beds of macrophytes dominated by *Triglochin* L. Pond 4 (6.7km south of Northcliffe) was a large ditch which had been excavated during road-making activities. It was sufficiently old to have become colonised by clumps of *Juncus*. Locality 5 (7.1 km south of Northcliffe) was a small, shallow roadside pool that entirely lacked macrophytes. Ponds 6 and 7 (10.8 km south of Northcliffe and 1.1 km south of Mt Chudalup, respectively) were in open coastal heath and sedgelands. Both had sandy bottoms and contained dark, humic water and few, if any, macrophytes.

Methods

Biological aspects

Each pond was thoroughly sampled with the zooplankton net described by Bayly (1982). Sampling was restricted to June and early July. In 1977, each pond was sampled three times at fortnightly intervals. In 1980, ponds 1-4 were sampled eight times at 2-4 day intervals. In 1990, ponds 1-4 were sampled once only—on 1 July.

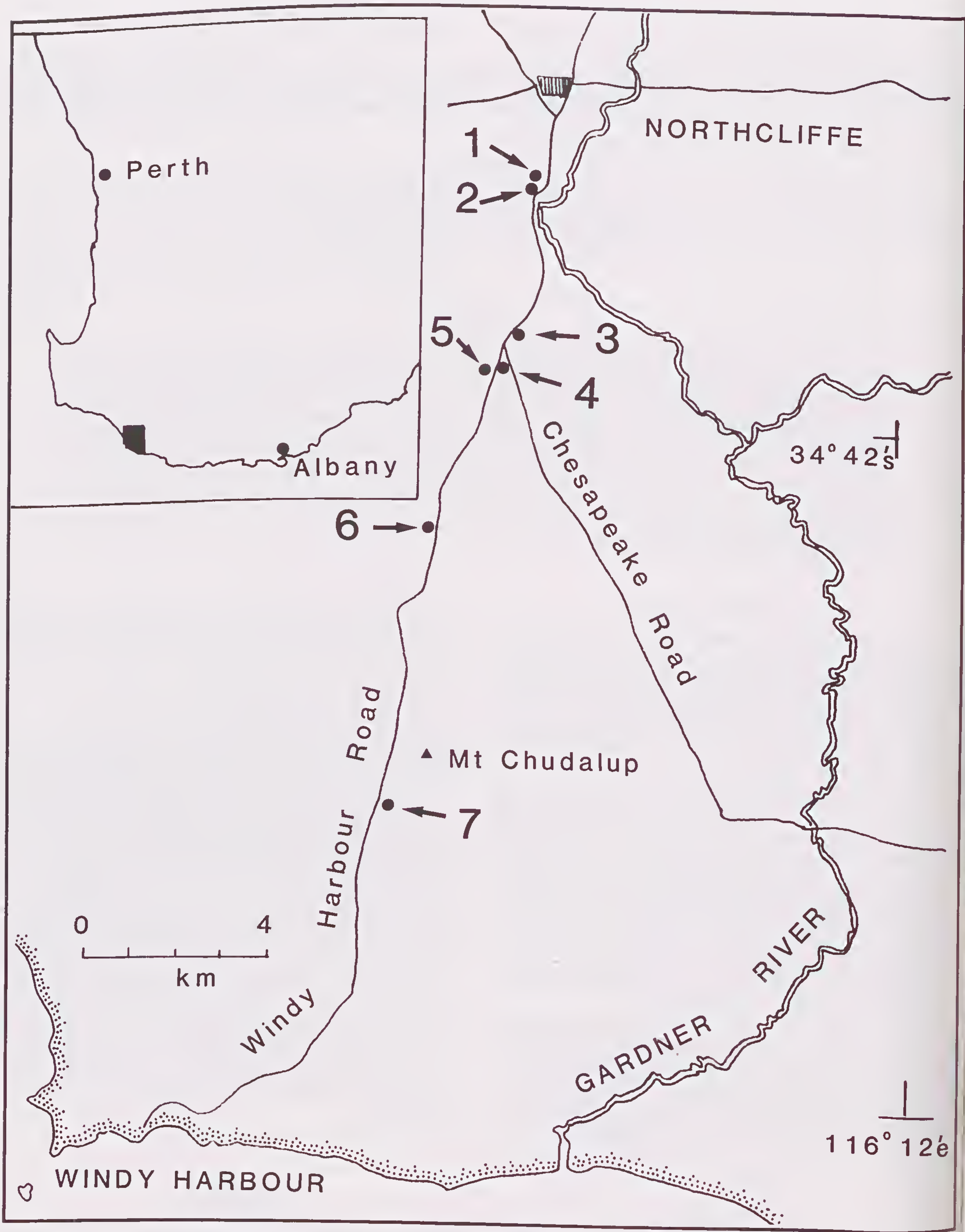

Figure 1 Map showing the study area in south-west Western Australia and the location of the seven ponds studied.

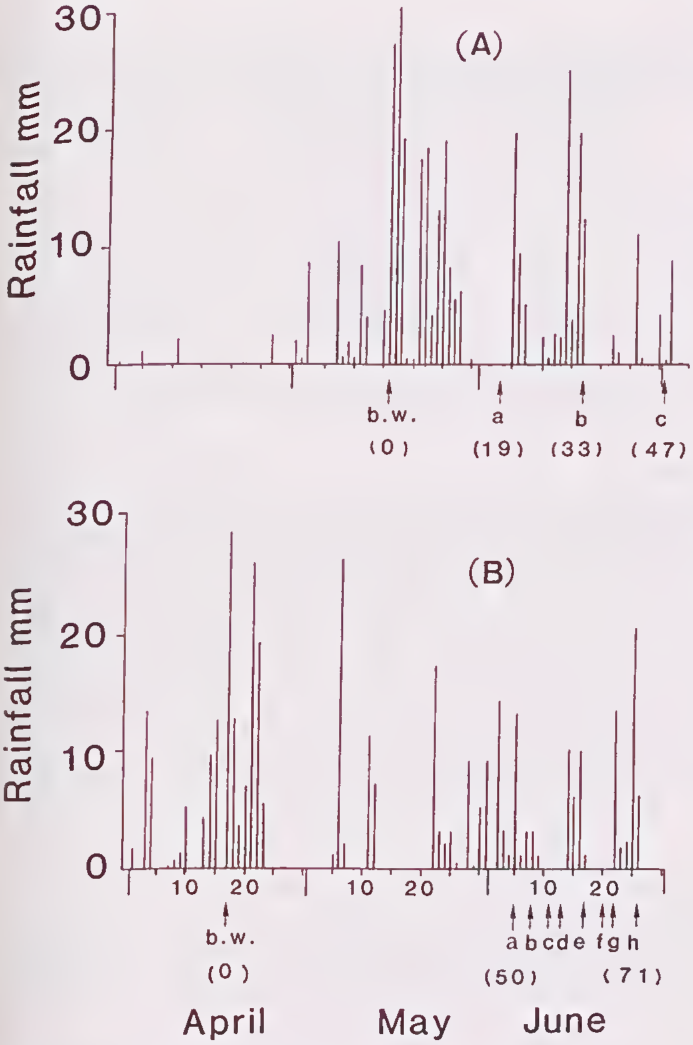

Figure 2 Rainfall recorded at Pemberton (near Northcliffe) from 1 April-30 June, A in 1977, and B in 1980. Break of the wet season (b.w.) occurred on 16 May 1977 and 17 April 1980. Number of days that elapsed after the break is given in parentheses below each of the three sampling days (a = 3 June, b = 17 June and c = 1 July) in 1977, and for the first and last of the eight sampling days (a = 5 June, b = 8 June, c = 11 June, d = 13 June, e = 17 June, f = 20 June, g = 23 June, h = 26 June) in 1980.

In the laboratory, collections were studied and sorted under a stereo-microscope. In 1977, the calanoid copepod species were subject to ordinal level of measurement and, for this reason, numbers (showing the order of abundance with the most abundant being 1) appear for them in Tables 3-7. Otherwise, the presence only (nominal level of measurement) of various taxa was recorded (indicated by the symbol X in Tables 3-7).

It was not possible to identify cyclopoid copepods and ostracods in all of the large number of samples taken during 1980; full identifications were obtained for the first series of samples taken on 5 June and also for those taken on 23 June. For other sampling dates in 1980 (except for cyclopoids at locality 1), the presence of cyclopoids and ostracods was recorded without further taxonomic resolution (see Tables 3-7). Detailed identifications of cyclopoids occurring at locality 1 were obtained for all of the 1980 collections.

Physico-chemical aspects

In 1977, three parameters (temperature, conductivity and pH) were measured using the methods described by Bayly (1982). In 1980, five parameters were measured: temperature, dissolved oxygen and REDOX potential were measured with a "Hydrolab 8000" (Hydrolab Corp., Texas) integrated, multiparameter instrument, while conductivity and pH were measured as in 1977.

In both 1977 and 1980 the depth of each pond was measured with the device described by Bayly (1982).

Results

Physico-chemical aspects

Results for 1977 are given in Table 1. Except for 3 June at locality 1, conductivities (K_{18}) were no greater than 270 µS cm^{-1}. All of the five localities at which pH measurements were made were acidic; localities 3 and 6 were strongly acidic. Daytime temperatures lay in the range 10.5-19.8°C. None of the ponds was deeper than 72 cm.

Table 1

Physico-chemical features of Northcliffe-Windy Harbour ponds in 1977

Locality number	Date	Maximum depth (cm)	Conductivity (K_{18}) (µS cm^{-1})	pH	Temperature (°C)
1	3 June	14	508		19.2
	17 June	38	167		14.9
	1 July	40	223		16.5
2	3 June	14	139		19.8
	17 June	39	129	6.2	14.4
	1 July	40	126		15.5
3	3 June	37	215		10.9
	17 June	50	185		12.4
	1 July	58	180	4.2	11.8
4	17 June	72	54		13.2
	1 July	60	71	5.1	13.1
5	3 June	24	77		12.7
	17 June	31	117	5.7	14.3
	1 July	32	142	5.6	10.5
6	3 June	25	234		14.3
	17 June	40	267	4.0	14.2
	1 July	40	270		10.6
7	3 June	45	169		17.4
	17 June	55	190		14.0
	1 July	56	251		12.1

Results for 1980 are presented in Table 2. Conductivity results were concordant with those obtained in 1977, the mean order for the locality numbers being 1>3>2>4. The pH of localities 1 and 2 was closely similar and remained fairly constant at about 6.0. Localities 3 and 4 were closely similar and highly acidic; pH lay in the range 4.2-4.6. For both dissolved oxygen and REDOX potential the mean values for the four localities showed the same order: 4>3>2>1. Water temperatures lay in the range 7.5-13.3°C. The maximum depth of all ponds showed a tendency to increase during the sampling period.

Biological aspects

The occurrence of micro-crustacean taxa in 1977, 1980 and 1990 is shown in Tables 3-7. A total of 35 taxa were recorded during this study.

Table 2

Physico-chemical features of Northcliffe-Windy Harbour ponds in winter of 1980. Except for maximum depth, the values given are means ± standard errors for 8 sampling days.

Locality number	Maximum depth (cm)[1]	Conductivity (K_{18}) (µS cm^{-1})	pH	Temperature (°C)	REDOX potential (mV)	Dissolved oxygen (mg l^{-1})
1	34-43	269±21	6.04±0.03	10.7±0.5	253±12	4.1±0.6
2	22-46	159±2	5.83±0.04	11.1±0.5	287±9	6.2±0.4
3	32-49	223±4	4.33±0.03	10.1±0.6	351±8	6.5±0.3
4	65-75	69±2	4.45±0.02	11.1±0.5	377±6	8.1±0.1

[1]The lower value of the range corresponds with the depth found on 5 June and the higher value corresponds with the depth recorded on 26 June.

Table 3

Northcliffe locality one. Occurrence of micro-crustacean taxa in samples taken on various dates in 1977, 1980 and 1990. The presence of taxa is indicated by "X" for mature individuals or "J" where only juvenile individuals were present. The relative abundance of Calanoida is indicated by 1 (most abundant) or 2 (less abundant).

TAXA	1977 3 June	1977 17 June	1977 1 July	1980 5 June	1980 8 June	1980 11 June	1980 13 June	1980 17 June	1980 20 June	1980 23 June	1980 26 June	1990 1 July
CALANOIDA					J	J	J	J				
Calamoecia attenuata Fairbridge			2									
Hemiboeckella andersonae Bayly		1	1						X	X	X	X
CYCLOPOIDA												
Austrocyclops australis (Sars)							X					X
Mesocyclops sp.			X	X					X		X	X
Metacyclops sp. (cf. *arnaudi*)				X	X	X			X			
OSTRACODA					X	X	X	X	X		X	
Bennelongia australis (Brady)	J	J	X							J		J
Cypretta viridis (Thompson)	J		X							J		X
Eucypris virens (Jurine)		X		J						X		
CLADOCERA												
Biapertura cf *macrocopa* (Sars)			X							X	X	
Ceriodaphnia sp.												X
Chydorus cf *sphaericus* (O.F.Muller)	X	X	X	X	X	X	X	X	X	X	X	X
Pleuroxus inermis Sars	X	X	X	X		X						X

Table 4

Northcliffe locality two. Occurrence of micro-crustacean taxa in samples taken on various dates in 1977, 1980 and 1990. The presence of taxa is indicated by "X" for mature individuals or "J" where only juvenile individuals were present. The relative abundance of Calanoida is indicated by 1 (most abundant) or 2 (less abundant).

TAXA	1977 3 June	1977 17 June	1977 1 July	1980 5 June	1980 8 June	1980 11 June	1980 13 June	1980 17 June	1980 20 June	1980 23 June	1980 26 June	1990 1 July
CALANOIDA												
Calamoecia attenuata Fairbridge	—	1	1	X	X	X	X	X	X	X	X	
Hemiboeckella andersonae Bayly	—	2	2	X	X	X	X	X	X	X	—	
CYCLOPOIDA					X	X	X	X	X		X	
Austrocyclops australis (Sars)	—	X	X	X								X
Mesocyclops sp.	—	X	X	X								X
Metacyclops sp. (cf *arnaudi*)				X						X		
OSTRACODA					X	X	X	X	X		X	
Bennelongia australis (Brady)	J	J	X									X
Cypretta viridis (Thomson)	J	X	X	X						X		X
Eucypris virens (Jurine)		X		X						X		
CLADOCERA												
Biapertura cf *macrocopa* (Sars)	—	—	X	—	—	—	—	—	X	X		
Chydorus cf *sphaericus* (O.F.Muller)	X	X	X	X	X	X	X	X	X	X	X	
Daphnia sp.												X
Pleuroxus inermis Sars	X	X	X									X
Simocephalus sp.												X

Table 5

Northcliffe locality three. Occurrence of micro-crustacean taxa in samples taken on various dates in 1977, 1980 and 1990. The presence of taxa is indicated by "X" for mature individuals or "J" where only juvenile individuals were present. The relative abundance of Calanoida is indicated by 1 (most abundant) to 3 (least abundant).

TAXA	1977 3 June	 17 June	 1 July	1980 5 June	 8 June	 11 June	 13 June	 17 June	 20 June	 23 June	 26 June	1990 1 July
CALANOIDA												
Calamoecia attenuata Fairbridge	—	1	2	X	X	X	X	X	X	X	X	X
C. elongata Bayly	—	2	1	X	X	X	X	X	X	X	X	X
Hemiboeckella searli Sars	J[1]	3	3	X	X	X	X	X	X	X	X	X
CYCLOPOIDA					X	X	X	X	X		X	
Mesocyclops sp.	X	X	—	X								
Paracyclops sp nov	—	X	X							X		X
Macrocyclops albidus (Jurine)												X
CLADOCERA												
Alona sp. nov.	X	—	—	X	X	X	X	X	X	X	X	
Alonella cf *excisa* (Fisher)	X	X	X	X	X	X	X	X	X	X	X	X
Biapertura cf *macrocopa* (Sars)	—	X	—	X	X	X	X	X	X	X	—	
B. longinqua Smirnov				X	X	X	X	X	X	—	X	
Camptocercus sp.				X	X	—	X	X	—	X	—	
Daphnia occidentalis Benzie	X	X	X	X	X	X	X	X	X	X	X	X
Graptoleberis sp.				X	X	X	X	X	X	X	—	
Monope reticulata (Henry)				—	X	—	—	—	X	X	—	
Scapholeberis kingi Sars	X	X	X	X	X	X	X	X	X	X	—	

[1]None mature, but copepodite stage V present and positively identifiable from the very unequal length of the furcal setae (see Bayly 1974, P.92).

Table 6

Northcliffe locality four. Occurrence of micro-crustacean taxa in samples taken on various dates in 1977, 1980 and 1990. The presence of taxa is indicated by "X". The relative abundance of Calanoida is indicated by 1 (most abundant) to 3 (least abundant).

TAXA	1977 17 June	 1 July	1980 5 June	 8 June	 11 June	 13 June	 17 June	 20 June	 23 June	 26 June	1990 1 July
CALANOIDA											
Boeckella geniculata Bayly	2	3	X	X	X	X	X	X	X	X	
Calamoecia attenuata Fairbridge	1=	2	X	X	X	X	X	X	X	X	X
C. elongata Bayly	1=	1	X	X	X	X	X	X	X	X	X
CLADOCERA											
Alonella cf *excisa* (Fisher)	X	X	—	—	X	X	X	X	X	X	X
Biapertura cf *macrocopa* (Sars)	X	—	—	—	—	—	X	—	X	X	
Monope reticulata (Henry)	X	—	—	—	—	—	X	—	—	—	
Scapholeberis kingi Sars			X	X	X	X	X	X	X	—	

In 1977, and omitting locality 4 which was not sampled on 3 June, the mean number of species per locality increased with time (3 June, 4.5 species; 17 June, 6.5 species; 1 July, 7.3 species) and the total number of species recorded per locality varied as follows: locality 1 (9 species), 2 (10 spp), 3 (10 spp), 4 (6 spp), 5 (8 spp), 6 (11 spp) and 7 (9 spp).

In 1980, the total number of species recorded from the various localities was as follows: locality 1 (10 species), 2 (9 spp), 3 (14 spp) and 4 (7 spp).

On 1 July 1990 the mean number of species per locality (localities 1-4) was 6.3. The total number of species was as follows: 1 (8 spp), 2 (7 spp), 3 (7 spp) and 4 (3 spp).

Discussion

There are two themes of particular interest associated with the limnology of the Northcliffe region: endemism and peculiar water chemistry. This study provides a basis on which to compare micro-crustacean colonization of acidic ponds in Western Australia, other parts of Australia, and in other countries.

Maly & Bayly (1991) and Frey (1991) have emphasised that many of the microcrustacean taxa in Western Australia do not occur in eastern Australia. Epicontinental seas covered much of Australia during part of the Early Cretaceous (ca. 120-110 Ma BP) and the western half of

Table 7

Northcliffe localities five, six and seven. Occurrence of micro-crustacean taxa in samples taken on various dates in 1977. The presence of taxa is indicated by "X" for mature individuals or "J" where only juvenile individuals were present. The relative abundance of Calanoida is indicated by 1 (most abundant) to 4 (least abundant).

LOCALITY NUMBER	5			6			7		
TAXA	3 June	17 June	1 July	3 June	17 June	1 July	3 June	17 June	1 July
CALANOIDA									
Calamoecia elongata Bayly	J	X	X			1			
C. tasmanica[1]					1	2	1	1	1
Hemiboeckella andersonae Bayly						3			
H. searli Sars				1	2	4	2	2	2
CYCLOPOIDA									
Mesocyclops sp.		J	X						
Metacyclops sp. (cf *arnaudi*)	X			X	X	X	X	X	
OSTRACODA									
Benelongia australis Brady	J							J	
Cypretta baylyi McKenzie		J							
Ilyodromus varrovillius (King)			J						J
CLADOCERA									
Alona sp. nov.						X			
Alonella cf *excisa* (Fisher)	X	X	X						
Amblyorhynchus sp.						X			
Biapertura imitatoria Smirnov							X		
Ilyocryptus sp.					X				
Neothrix armata Gurney	X	X	X	X		X	X	X	X
Rak obtusus Smirnov & Timms						X			
Scapholeberis kingi Sars					X	X		X	X

[1] The form figured by Bayly (1979, figs. 8a-b) not *C. tasmanica subattenuata* (Fairbridge)

Western Australia was at times cut off from two or three islands to the east (Morgan 1980, BMR Palaeogeographic Group 1990) before the seas retreated later in the Cretaceous. Despite the retreat (and the fact that the extensive flooding anteceded Australia's separation from Antarctica), this event may have produced a zoogeographical legacy that has not been obliterated by dispersal. An alternative or additional factor in the distinctness of species assemblages in the southeast and southwest is the marine incursions into central Australia from the Late Eocene through to the mid-Miocene (Nelson 1981).

Pond 3 is the type locality of *Daphnia occidentalis* which was described by Benzie (1986) mainly from material collected during the present study. Benzie (1986) produced evidence that *D. occidentalis* is an ancient relict species whose origins go back at least to the late Cretaceous (*ca* 70 Ma BP). That such an ancient species should presently be known only from highly acidic waters in the present study area may be taken as further evidence that these environments have been in existence in the far south-west of Australia for a long period. The occurrence of an abundance of *D. occidentalis* in pond 3 (pH 4.2-4.5) runs counter to the statement of Okland & Okland (1986) that "the genus *Daphnia* is generally absent below pH 5.0-5.5".

Another ancient relict species that occurs in the region of the Northcliffe ponds, the extraordinary and enigmatic fish *Lepidogalaxias salamandroides* Mees, also has clear acidophilic tendencies; Christensen (1982) showed that the mean pH of waters inhabited by this fish was only 5.4 (range 3.7-6.8). Fifteen specimens of this species were captured in the plankton net at locality 6 on 5 June 1980 when the pH was 3.7.

Calamoecia elongata, which was described by Bayly (1979), occurred in ponds 3, 4, 5 and 6. This species is one of the seven (probably eight) out of the 19 freshwater centropagid species recorded from Western Australia that is endemic to that State (Maly & Bayly 1991, Table 1) and is presently unknown outside the Northcliffe region. The *Paracyclops* Claus occurring at locality 3 is a new species known only from the Northcliffe-Albany region (D W Morton, personal communication) Both of these copepod species are clearly capable of tolerating abnormally high acidity. A peculiar form (new sub-species?) of *C. tasmanica* s.l. (see Bayly 1979 Figs 8a-b) occurred at localities 6 and 7, and is presently known only from acidic waters in that vicinity.

Several acidophilic cladoceran species occurred at localities 3 (Table 5), 4 (Table 6), 6 and 7 (Table 7). *Biapertura imitatoria* Smirnov was described from locality 7 (Smirnov 1989) and is known only from that strongly humic site. *B. longiqua* Smirnov is also acidophilic; Smirnov & Timms (1983) commented that "most of the known habitats are acid waters on sand". *Monope reticulata* (Henry) has not previously been recorded outside of New South Wales where it is "usually found in acid water" (Smirnov & Timms 1983). *Rak obtusus* Smirnov and Timms is known only from acidic waters (mostly in the pH range 4.5-5.5) in New South Wales and Queensland (B V Timms, personal communication) and Northcliffe locality 6 which had a pH of 4.0 on 17 June, 1977 (Table 1).

The very high acidity of some of the ponds did not result in a lowering of species richness. In fact, pond three, whose pH in 1977 and 1980 lay in the range 4.2-4.5 (compared with pH *ca* 6.0 in ponds 1 and 2), yielded 10 species in 1977 and 14 in 1980, and had the highest mean richness within the seven ponds over these two years. This suggests that the micro-crustacean communities of this region (the "southern acid peat flats" of Pusey & Edward 1990) have, over a long period of time, developed an unusually high degree of tolerance of excessive acidity. In contrast, overseas studies (Roff & Kwiatkowski 1977, Confer *et al*. 1983) have reported a decrease in the species richness of zooplankton communities with increasing acidity. The absence of ostracods from localities 3, 4 and 6 (highly acidic) may be significant. In the Northcliffe region, the age and spatial heterogeneity, for example macrophyte diversity, of a pond, may exert a greater influence on species richness than low pH. The lowest number of species was recorded at localities 4 and 5. Pond 4 was of recent artificial origin and pond 5 entirely lacked macrophytes.

Boeckella geniculata Bayly, *Hemiboeckella andersonae* Bayly and *Calamoecia attenuata* (Fairbridge) are all endemic to south-western Australia but not restricted to acidic waters.

Pusey & Edward (1990) studied two sites (their numbers 8 and 9) located along the Northcliffe-Windy Harbour Road. Their sites were sampled five times over two years, and they recorded 14 taxa of micro-crustaceans. Ten taxa common to their survey and the present study were: *Calamoecia attenuata*, *C. tasmanica* s.l., *Macrocyclops albidus* (Jurine), *Metacyclops* sp. (cf. *arnaudi*), *Cypretta*, *Ilyodromus*, *Biapertura*, *Neothrix armata* Gurney, *Simocephalus* and *Chydorus*.

Bunn & Davies (1990) maintained that the stream fauna of south-western Australia is impoverished, not only in world comparisons, but also relative to that of south-eastern Australia. Regarding the latter comparison, the existing data for the micro-crustaceans of temporary standing waters are rather too limited, not readily comparable, and somewhat contradictory. Morton & Bayly (1977) found some 60 taxa in their study of 53 pools in Victoria whereas the present study found 35 taxa in seven ponds. Lake *et al.* (1989) recorded 30 taxa from a Victorian pond that was sampled 13 times over some seven months, but the Northcliffe pond with the richest assemblage (locality 3) yielded only 15 species from 13 samplings restricted largely to the month of June (but in more than one year). Some evidence contradicts these apparent trends; the total non-marine centropagid fauna (belonging to the genera *Boeckella*, *Hemiboeckella* and *Calamoecia*) of Western Australia amounts to 19 species while that for Victoria and Tasmania is 17 and 15 species respectively (Maly & Bayly 1991). Except possibly for *Calamoecia gibbosa* (Brehm), all of the Western Australian calanoids listed by the latter authors occur in the South West Botanical Province (within Western Australia the great majority of calanoids are found only there) so species density is similar in both regions; the South West Province of Western Australia and Victoria are of very nearly equal area (see Marchant 1973). Perhaps the more common ability of lentic taxa to produce resistant eggs has prevented exceptionally dry periods from extinguishing species to the degree suggested by Bunn & Davies (1990) for the stream fauna of south-western Australia.

Some observations are possible on species succession in this study. The 1977 sampling was instructive from the viewpoint of early succession. Amongst the calanoids, *Hemiboeckella searli* Sars was one of only three species encountered on the first sampling date (3 June) in 1977; at locality 3 (Table 5) none of this species was mature but copepodite stage V had been reached, and at locality 6 (Table 7) the population was very largely immature but a few adults were already present. If it is assumed that localities 3 and 6 came into existence at the break of the wet season, then, with temperatures that prevail in this region, it is inferred that this species is capable of developing from a resting egg to an adult in 19 days. However, allowing for delays in run-off before ponding occurs, the true time for completion of the life-cycle would be shorter than this. The population of *H. searli* was more advanced at locality 7 on 3 June, but this site was at the very bottom of a major depression, the deepest at first sampling (Table 1), and probably the first of the series to contain water. Bayly (1978) pointed out that *H. searli* (and *Hemiboeckella* generally) shows an exceptionally high degree of sexual dimorphism in size. I suggested that this might enhance the efficiency of food exploitation by allowing the consumption of an exceptionally wide range of particle sizes in situations such as a temporary pool immediately after formation where interspecific competition is likely to be minimal.

Certain other species also appear characteristic of the very early phases of succession, perhaps qualifying as fugitive species *sensu* Hutchinson (1951). Thus *Metacyclops* sp. (cf. *arnaudi*) appeared very early at localities 5-7 (Table 7) in agreement with the findings of Morton & Bayly (1977) and Lake *et al.* (1989) for *M. arnaudi* (Sars) in temporary waters in Victoria.

In 1980, sampling commenced too long after the break of the wet season for observation of early stages in succession. However, two observations, together indicating variable behaviour of *Hemiboeckella andersonae*, are possible. First, at locality 1 (Table 3) juvenile calanoids only were present from 8-17 June to be replaced by mature individuals of *H. andersonae* on 20 June which was 65 days after the break of the wet season. Second, at locality 2 (Table 4) the disappearance of a population of *H. andersonae* was observed; by 17 June it was scarce, on 20 and 23 June a very few adults were found, and by 26 June (70 days after the break) none were found. At this point, *Calamoecia attenuata*, which on 5 June was scarce, was still abundant at locality 2.

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